

A gridded database of Arctic sea ice extending back to the 1800s

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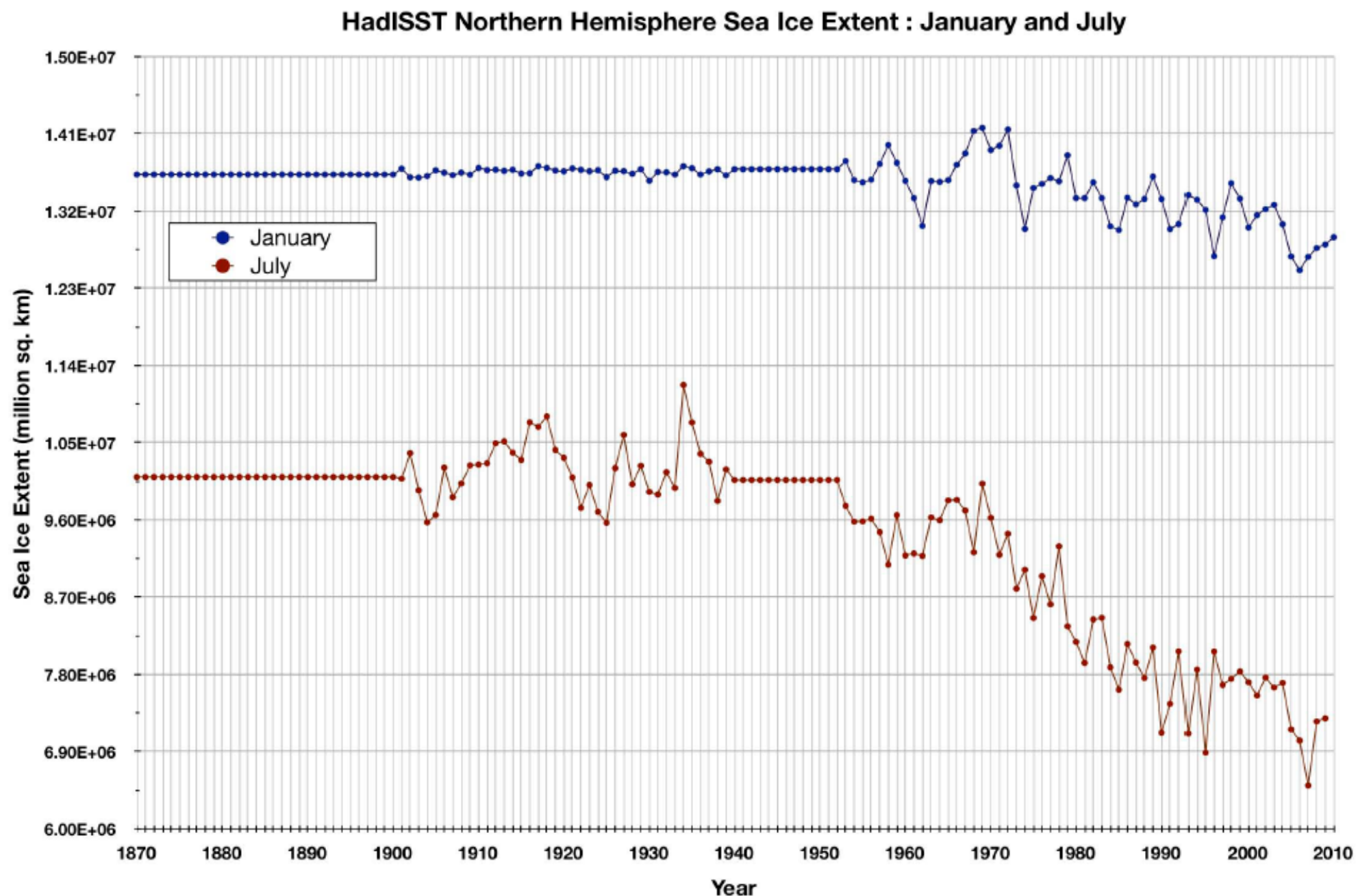
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(Image courtesy SNAP/UAF)

Motivation

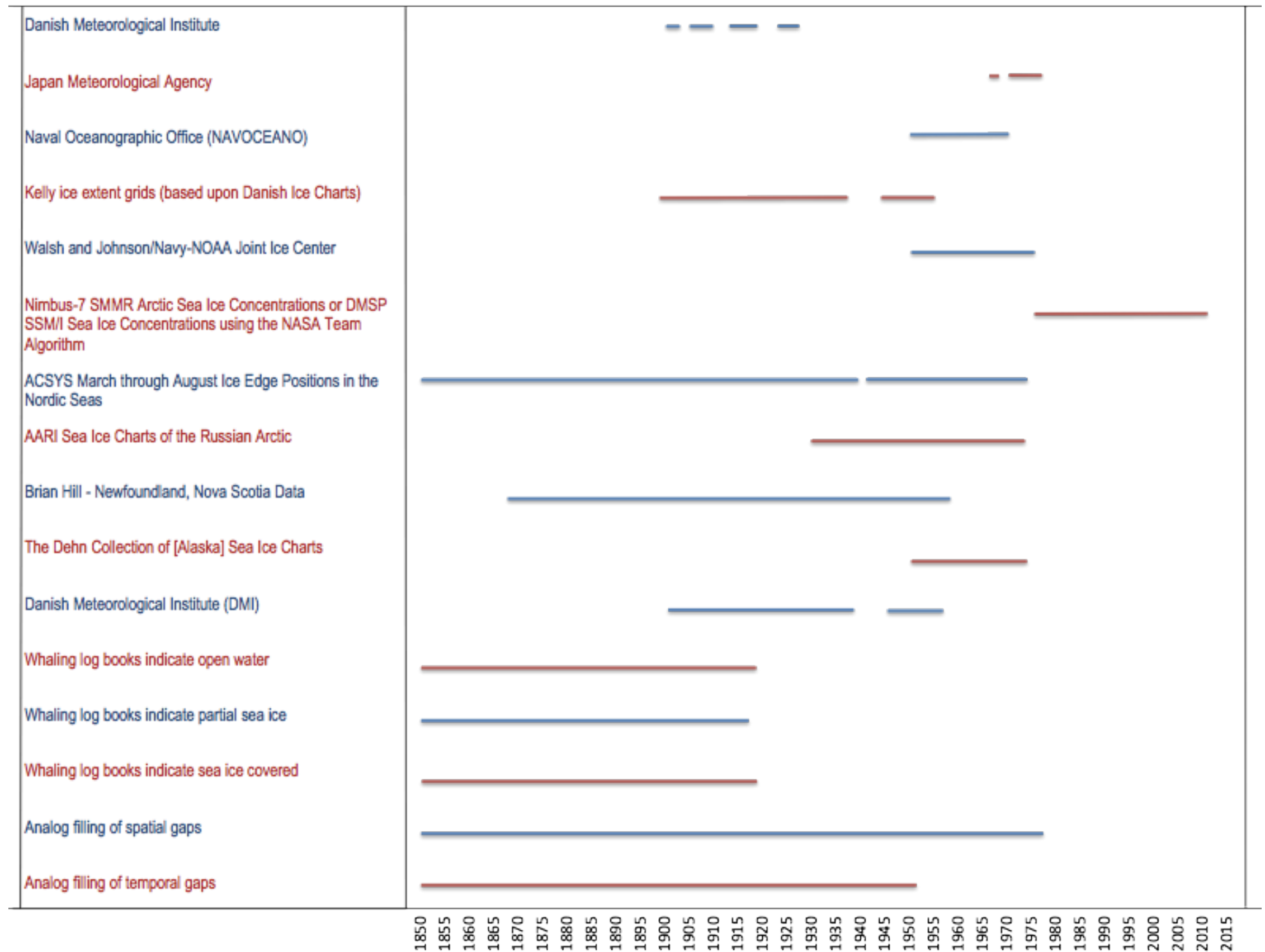
- A perspective on recent sea ice trends requires information pre-dating the satellite era
- Pre-satellite sources of sea ice data exist, but they are diverse and often undigitized
- Existing products such as the Hadley Centre's HadISST1 illustrate the need for a more homogeneous record:



Objectives

- **A digital sea ice atlas that maximizes the useful information on historical sea ice conditions**
 - consistently formatted ($\frac{1}{4}^{\circ}$ latitude x $\frac{1}{4}^{\circ}$ longitude) through time
 - monthly, back to 1850
 - including a space-time reconstruction over areas without observations
- **Documentation that includes**
 - descriptions of all data sources and a source-information map for each month
 - description of the interpolation procedure (for missing data)

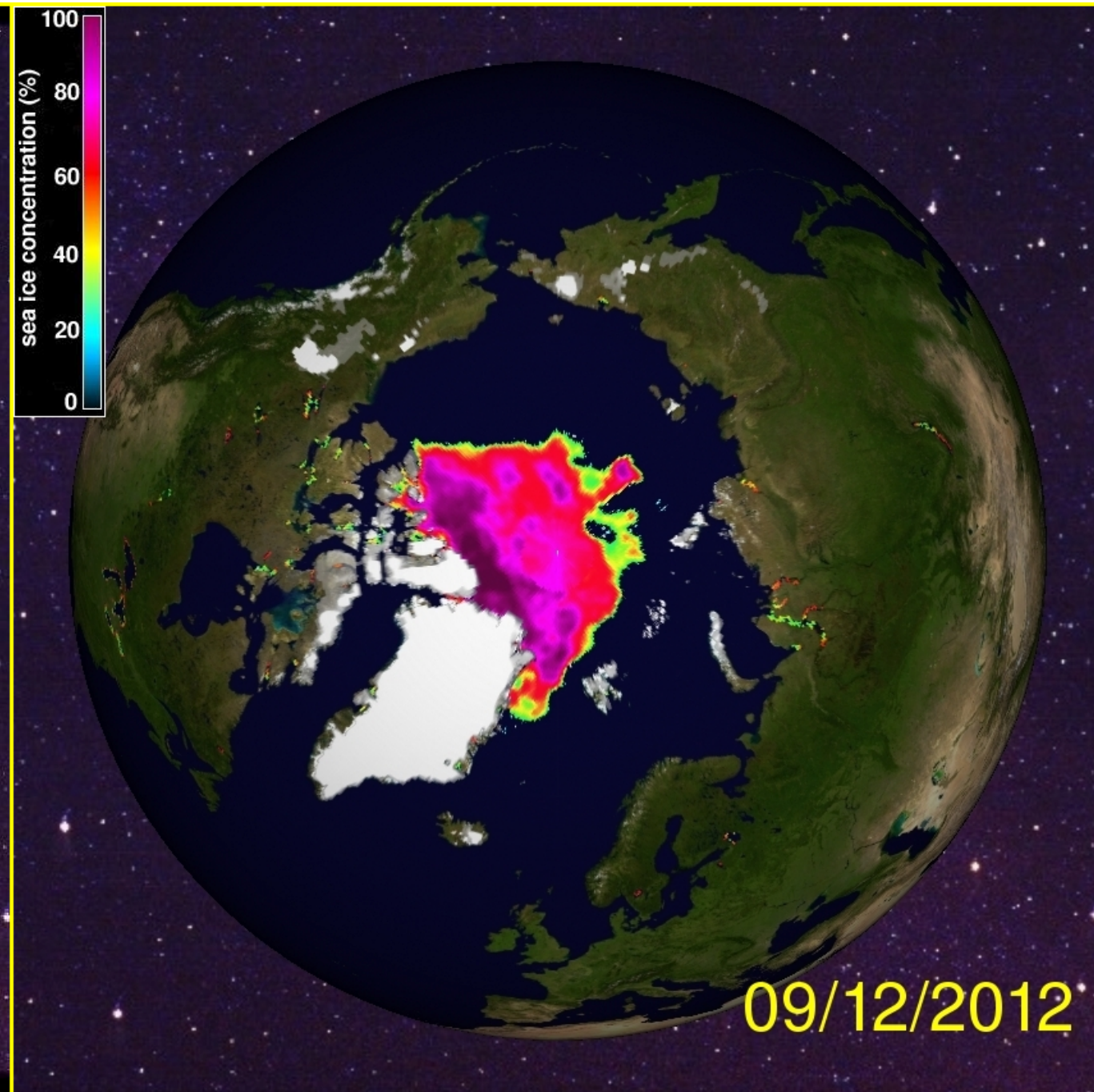
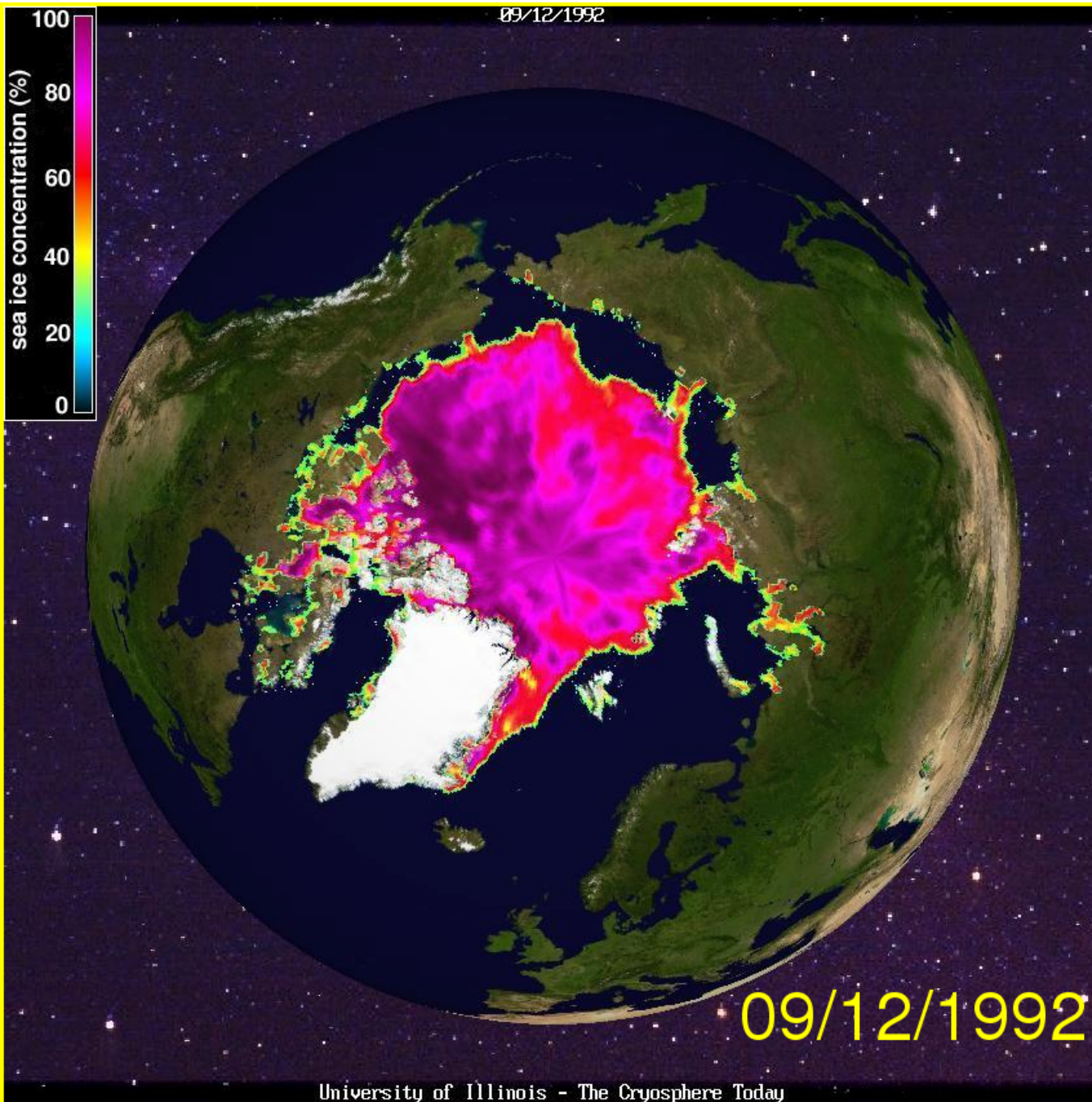
Primary data sources



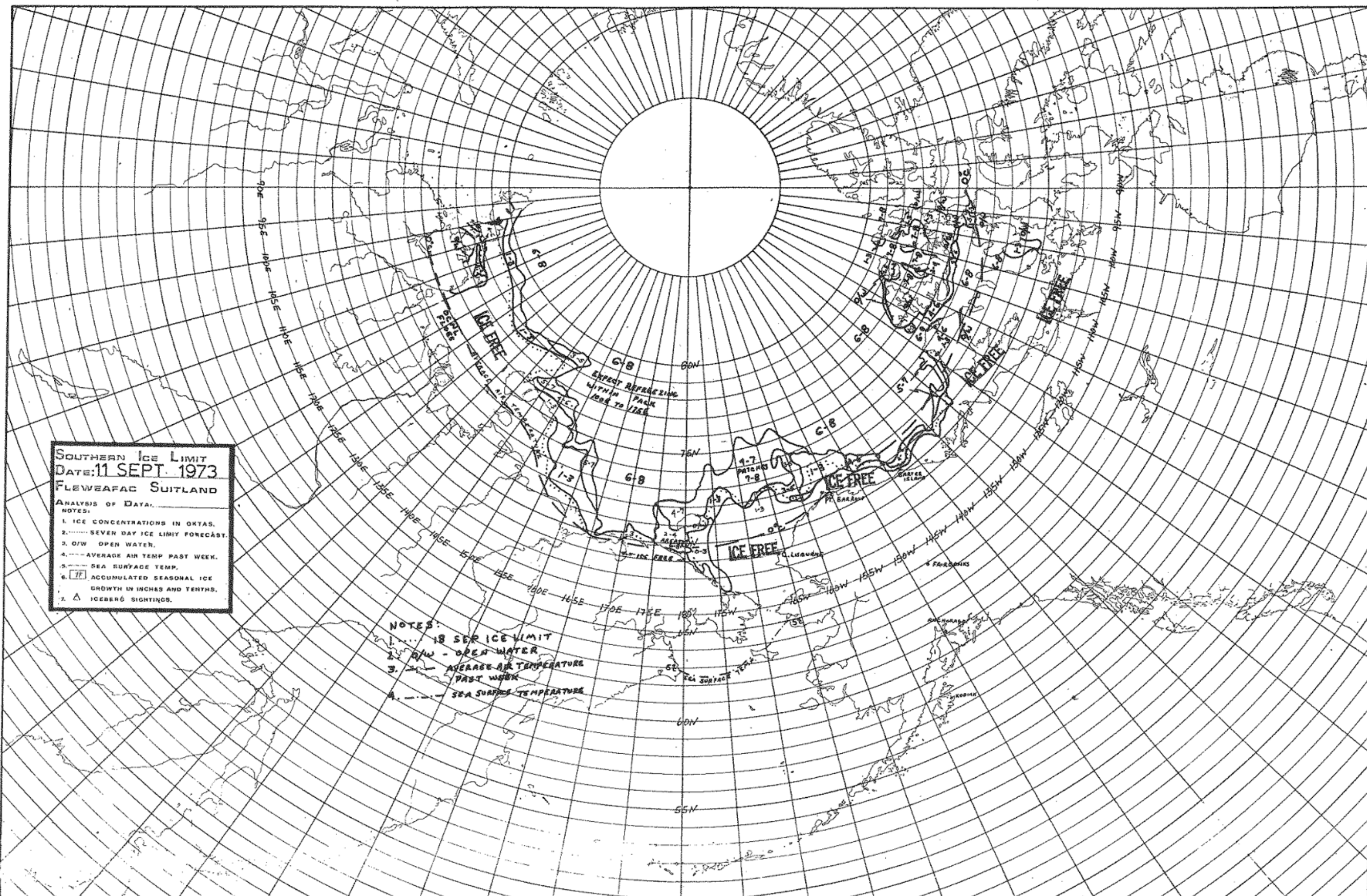
Satellite passive-microwave-derived sea ice concentrations

Sep. 12, 1992

Sep. 12, 2012



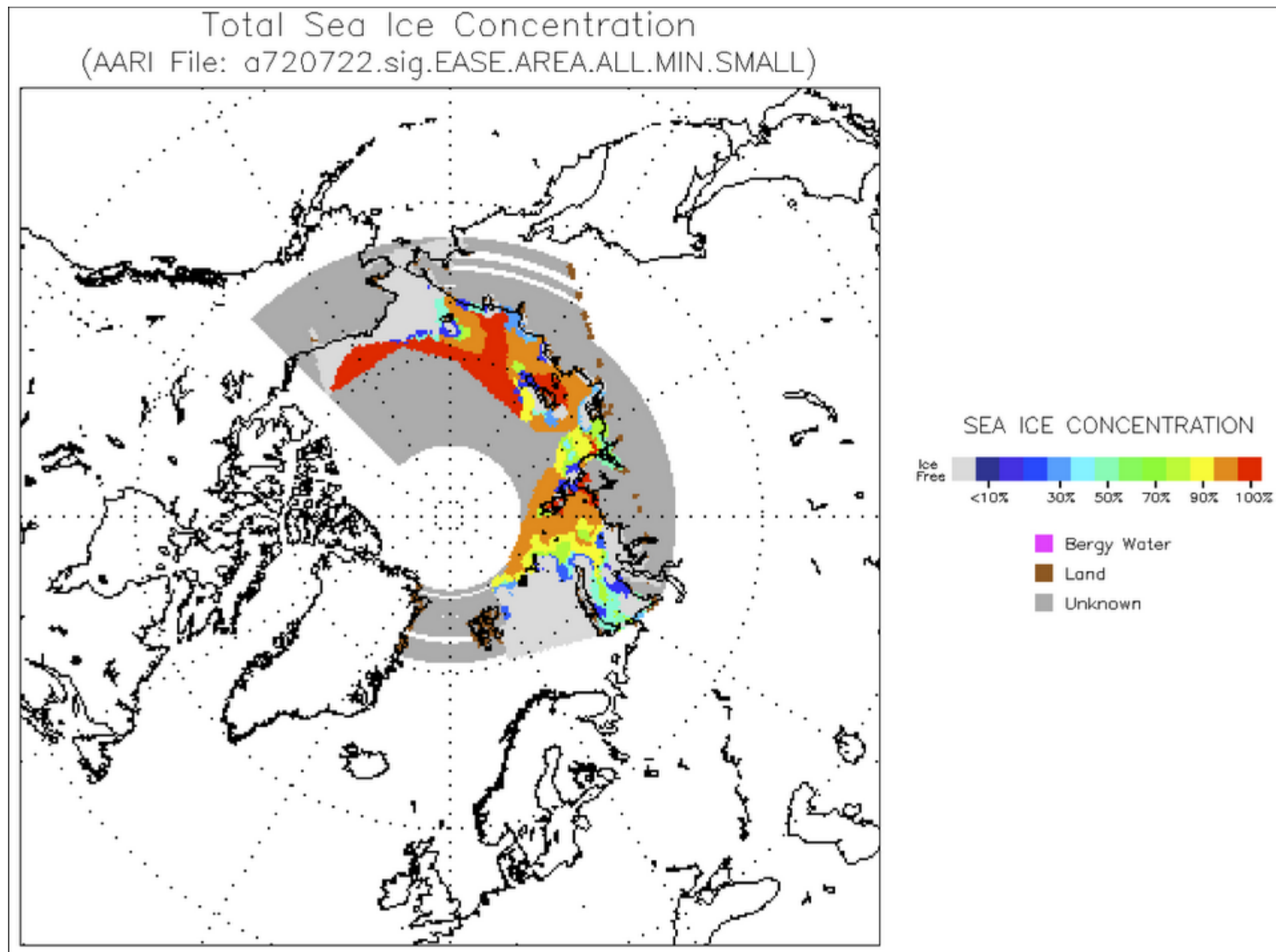
National Ice Center chart from the 1970s



Portion of sample chart from Dehn collection (8 Sept. 1953)



Sample ice concentration chart from AARI (Russia)



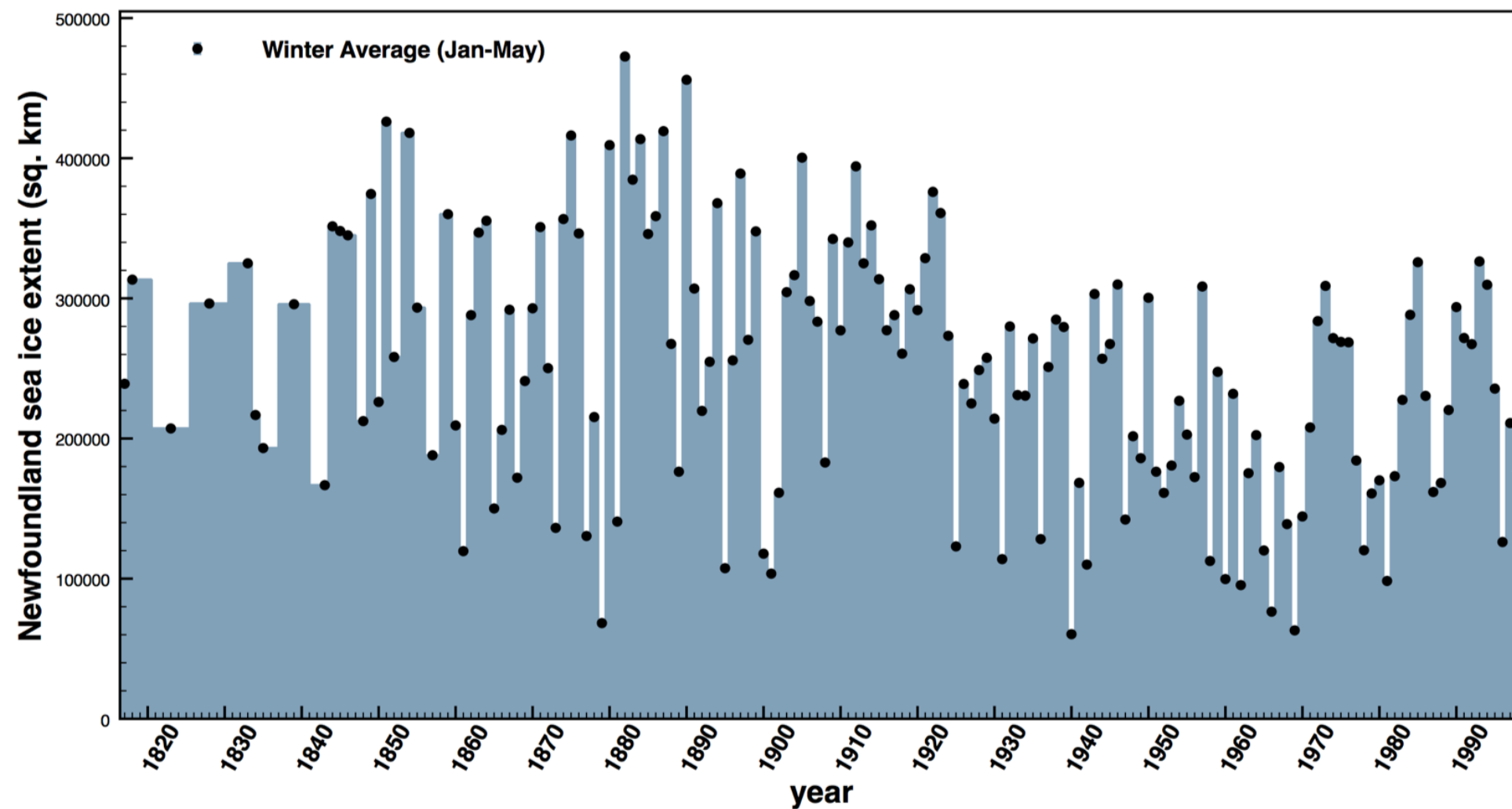
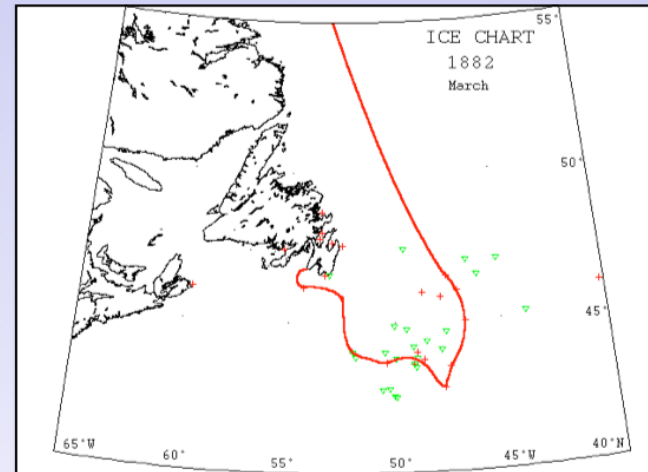
Danish Meteorological Institute (DMI): charts, narratives back to 1870s



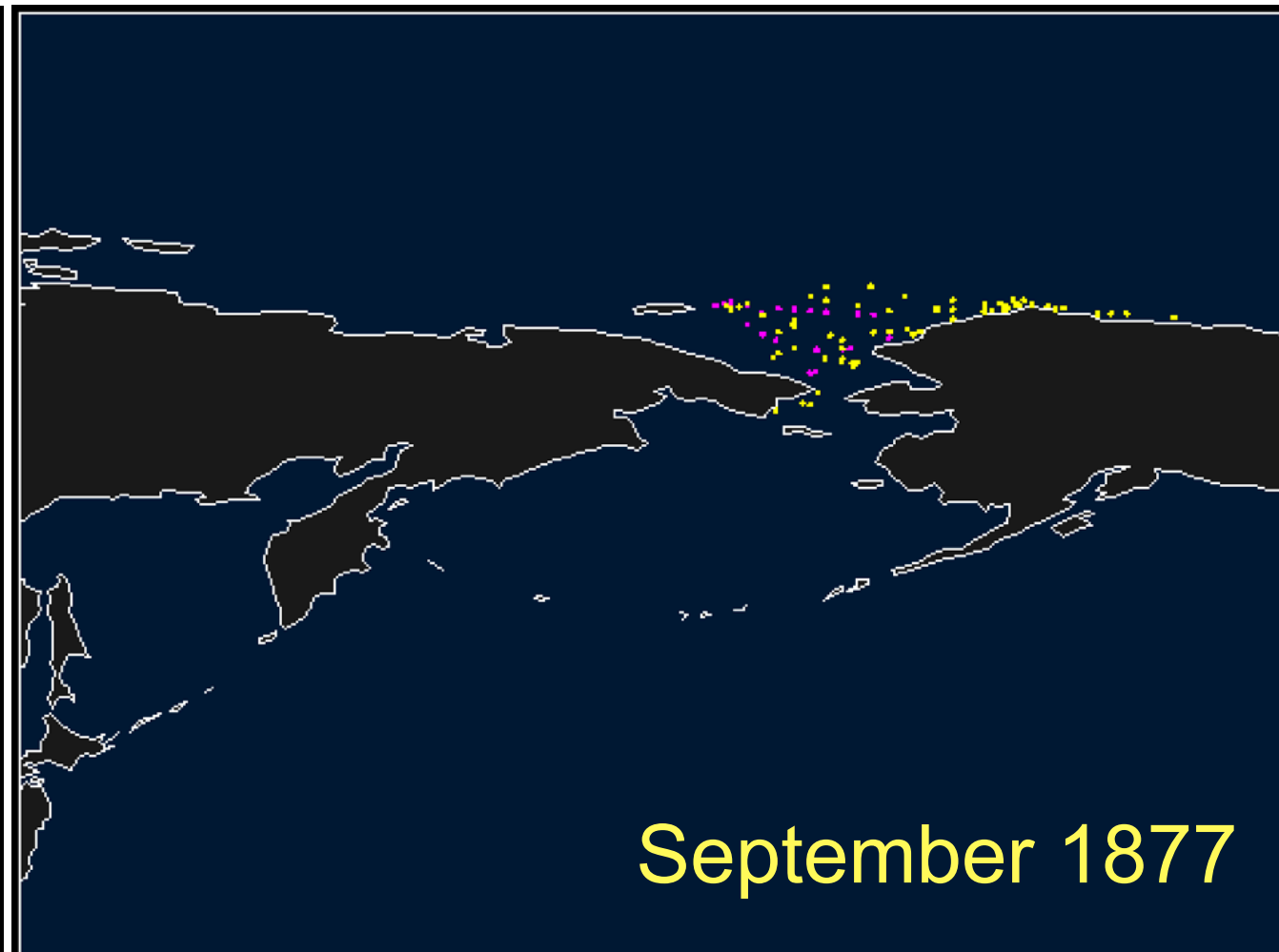
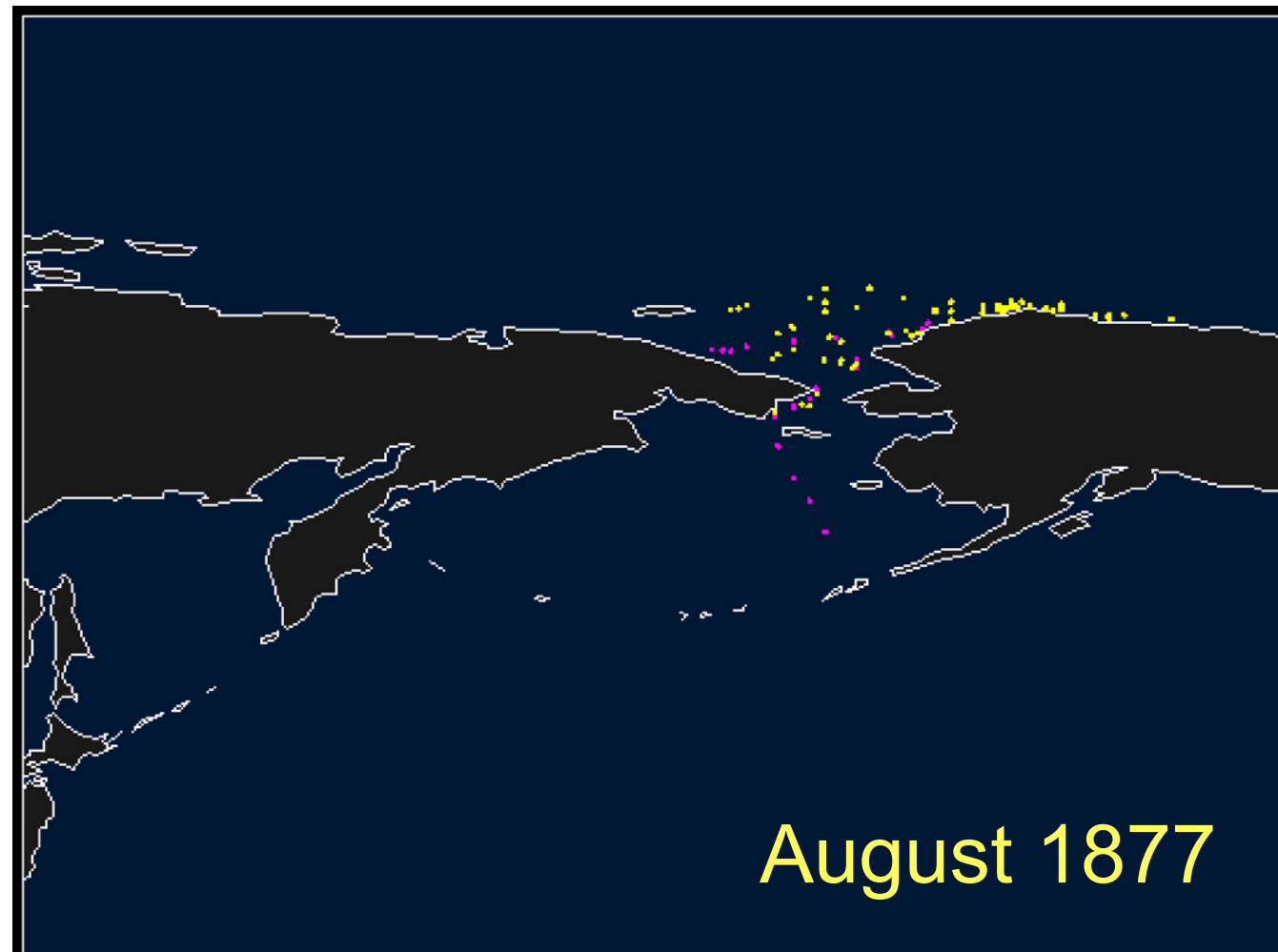
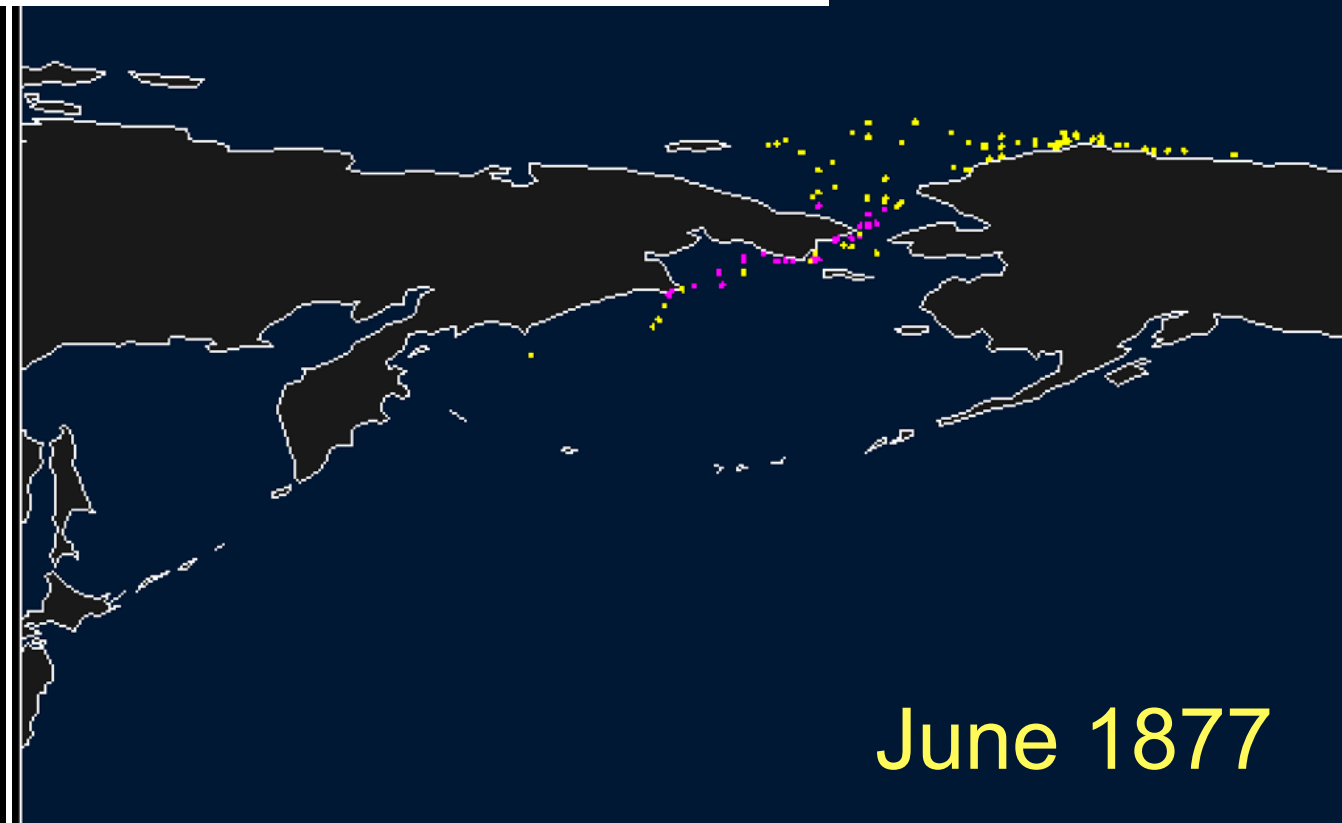
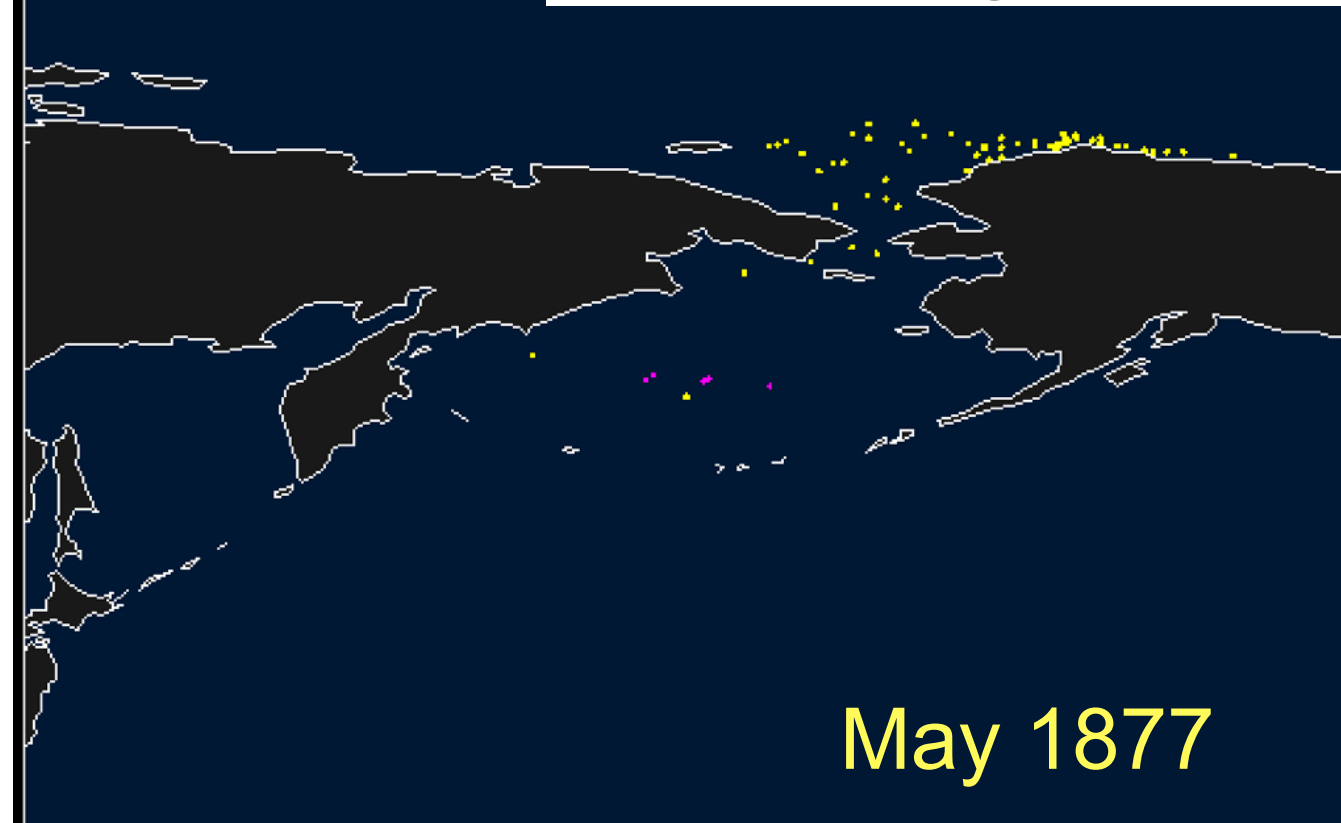
June 1924

National Research Council of Canada (Brian Hill)

NRCC

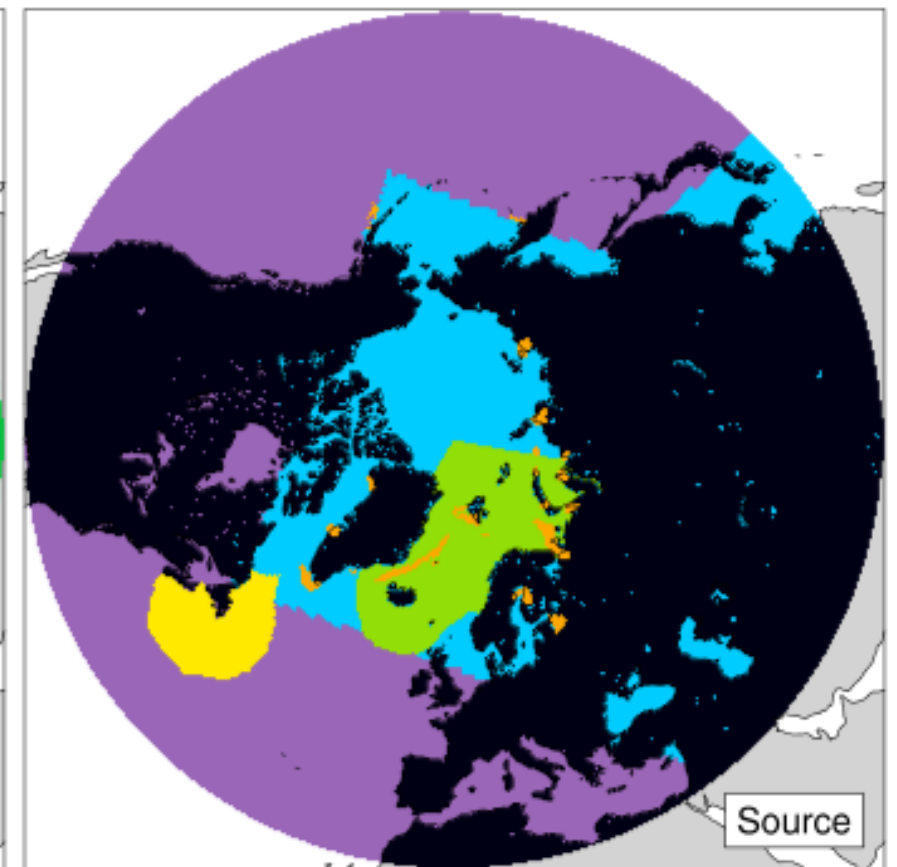
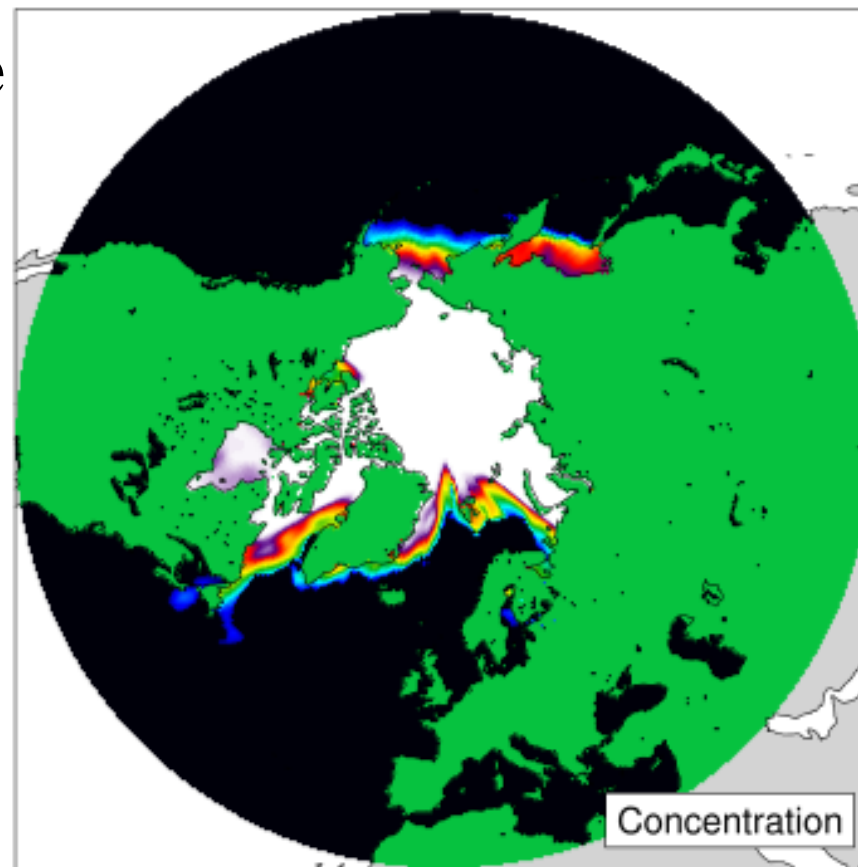


Whaling ship ice observations

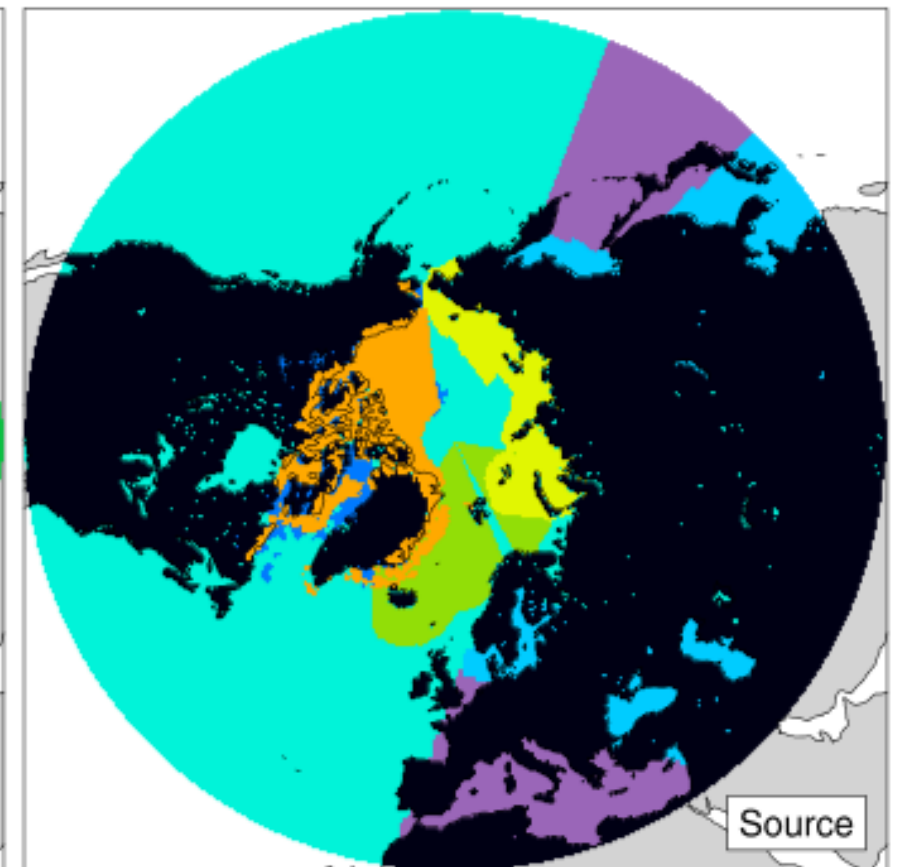
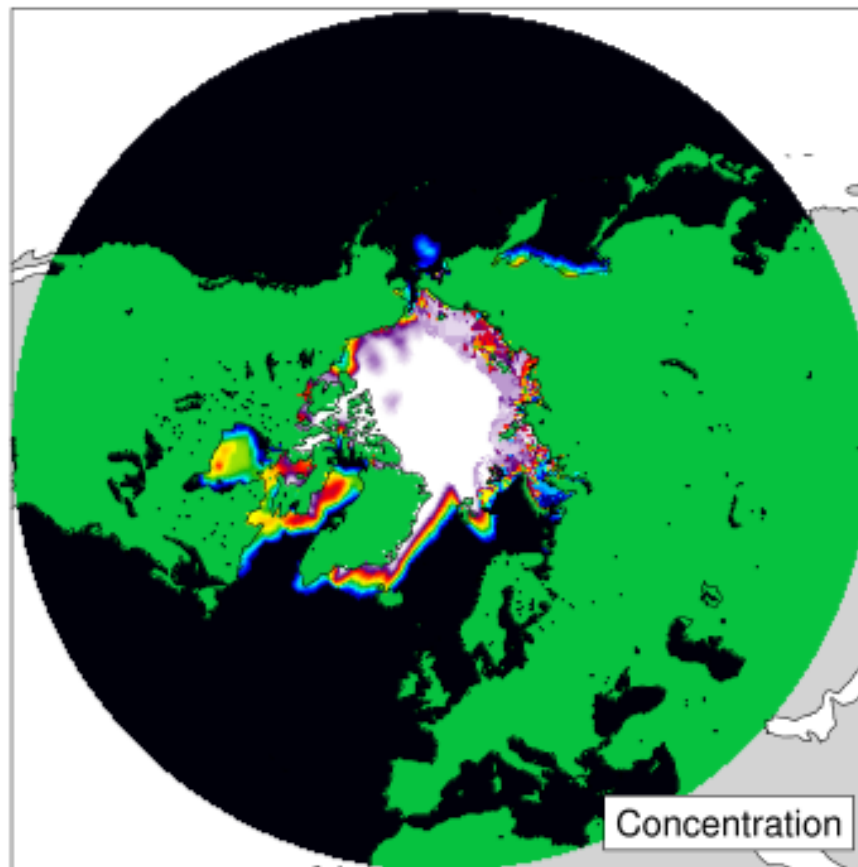


**Examples: synthesized ice
concentration maps (left)
and source maps (right)**

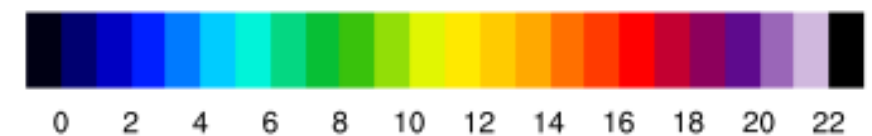
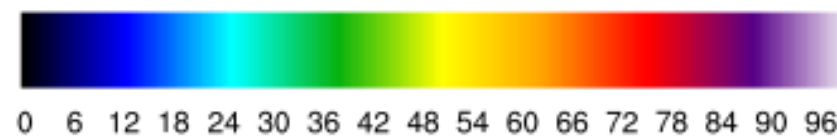
April 1935



July 1956



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Value-added steps

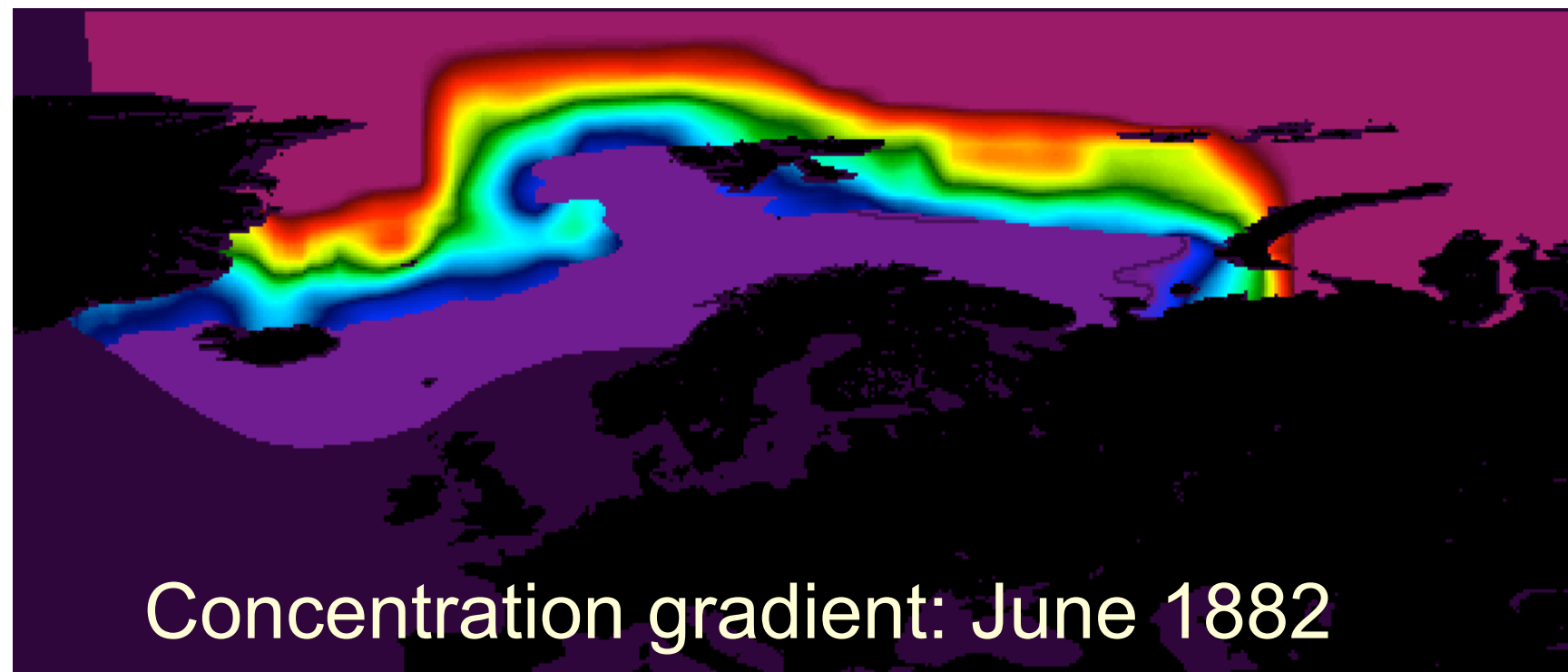
- **For areas and months with “ice-edge” information available, specification of ice concentration gradient at ice edge**
- **Analog-derived estimates to fill in missing data**

Specification of ice-edge concentration gradient

From this:



to this:



Analog approach for data fill-in

- (1) For each grid point “p” with some missing data in calendar month m and year y, areas with existing data in m-y are compared with calendar month m of all years 1900-2000 to select the best analogs. (If there is no data at all in month m and year y, the nearest month with some data is used for analog selection).**
- (2) If the three best analog years do not have data at point p, the search is repeated by limiting the analog candidates to 1953-2000.**
- (3) If step (2) does not produce three analogs with data at point p, then fewer than three analogs are used.**
- (4) Point p is “filled in” with the average concentration of the (up to) 3 best analog fields.**

Advantages and disadvantages of analog approach

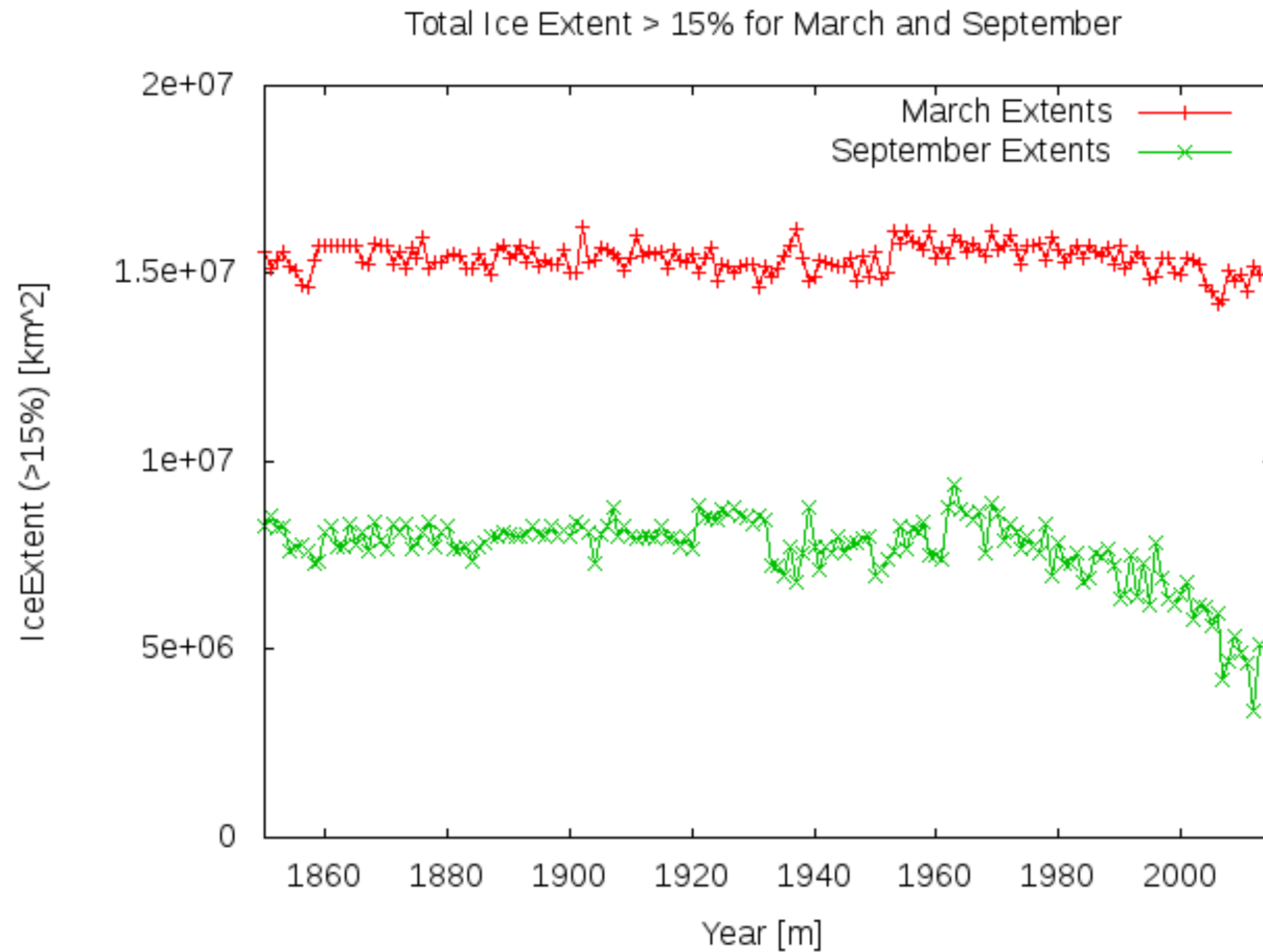
Advantages:

- **Uses observed data as basis for estimates of missing concentrations**
- **Eliminates need for basis functions that may not capture “unique” spatial characteristics of ice edge and concentration distribution**

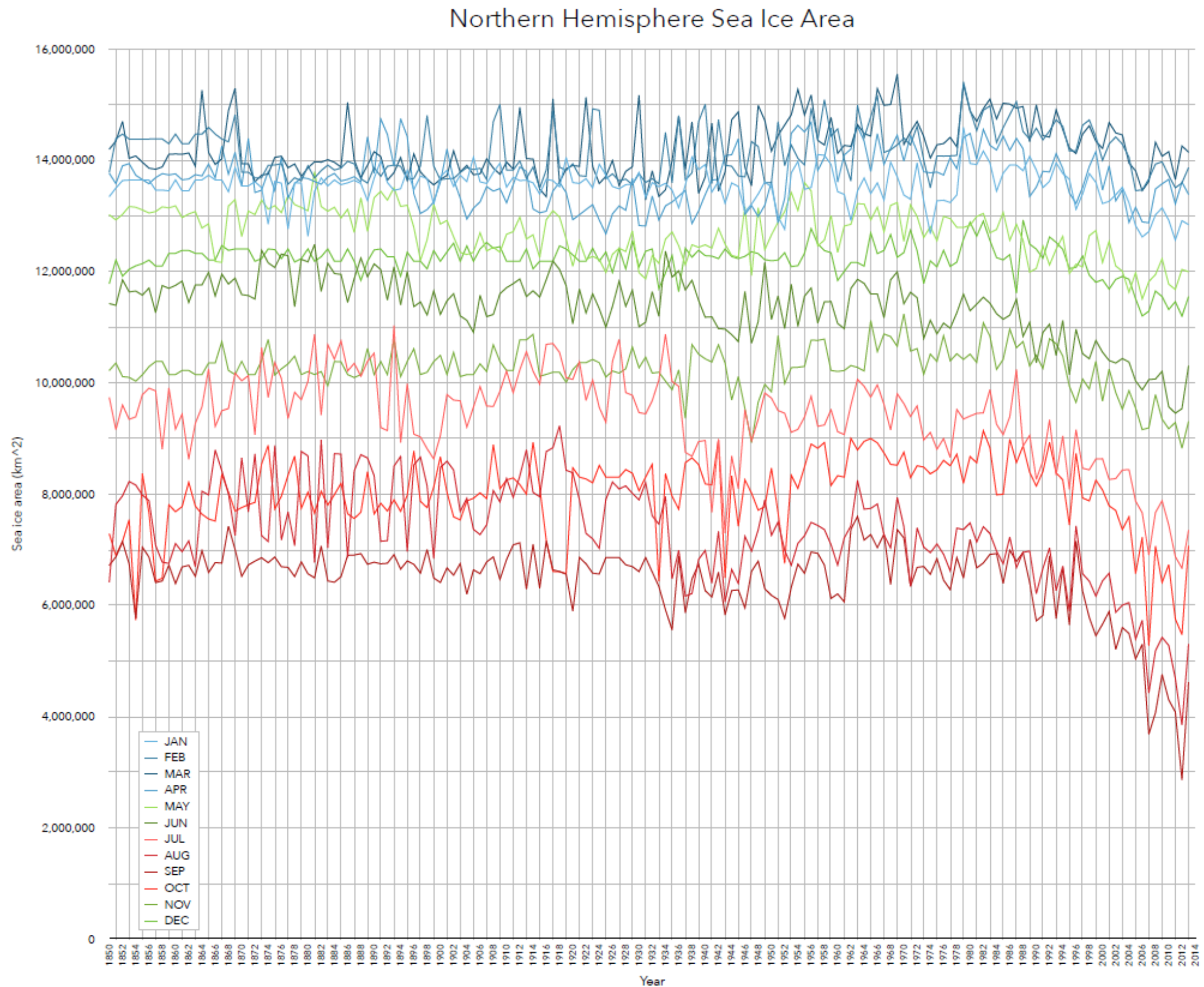
Disadvantages:

- **Selected analogs are biased toward period with more data, i.e., recent decades**
- **Spatial patterns of sea ice variability may have changed in the time since 1850**

Time series of pan-Arctic ice extent, 1950-2013: March and September



Calendar-month time series of pan-Arctic sea ice area. 1850-2013



Most extreme September minimum ice areas from three time slices:

1950-1900

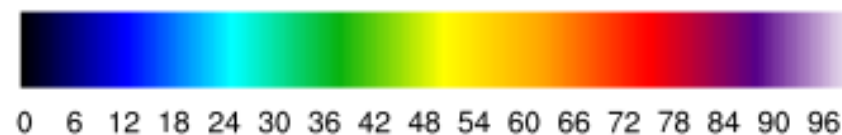
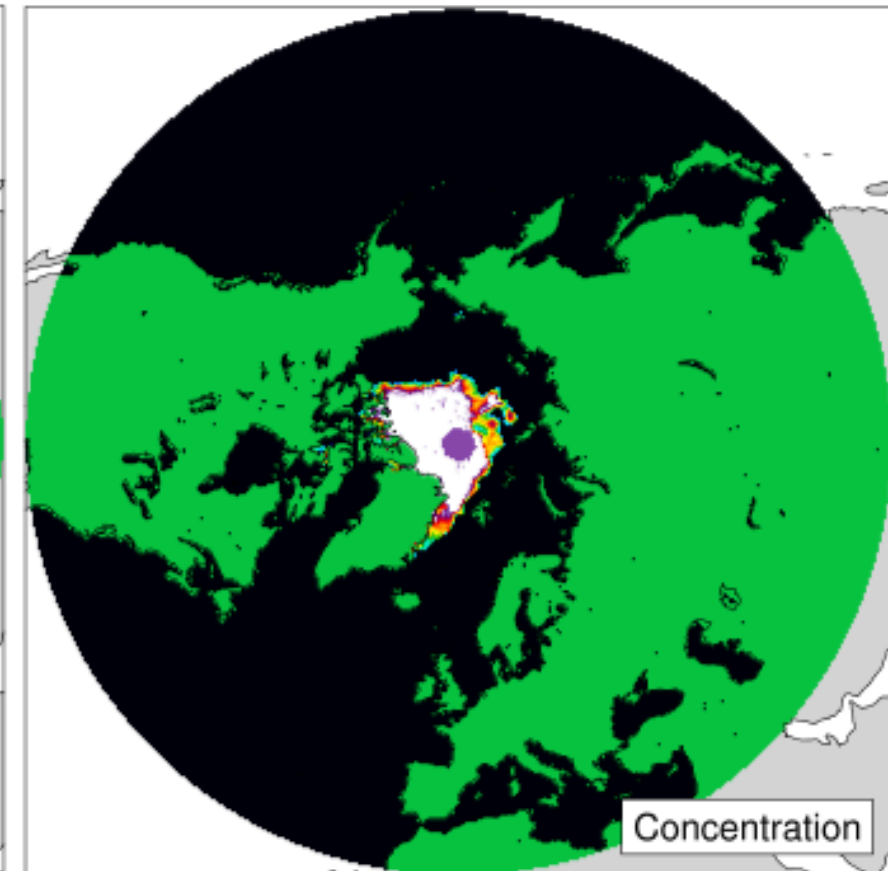
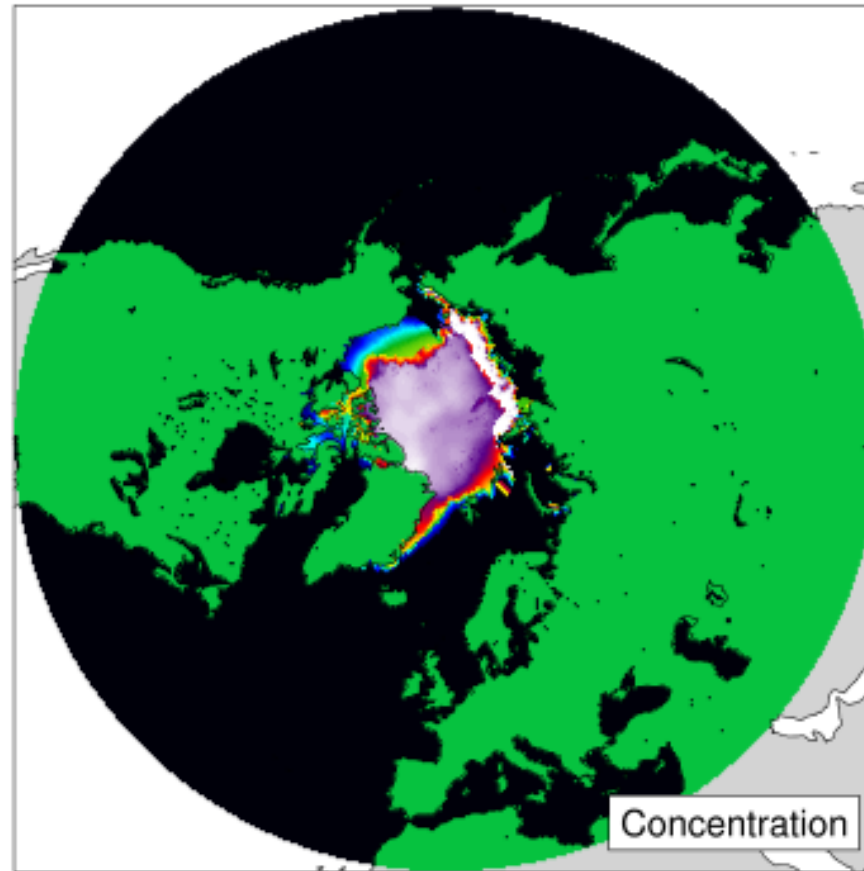
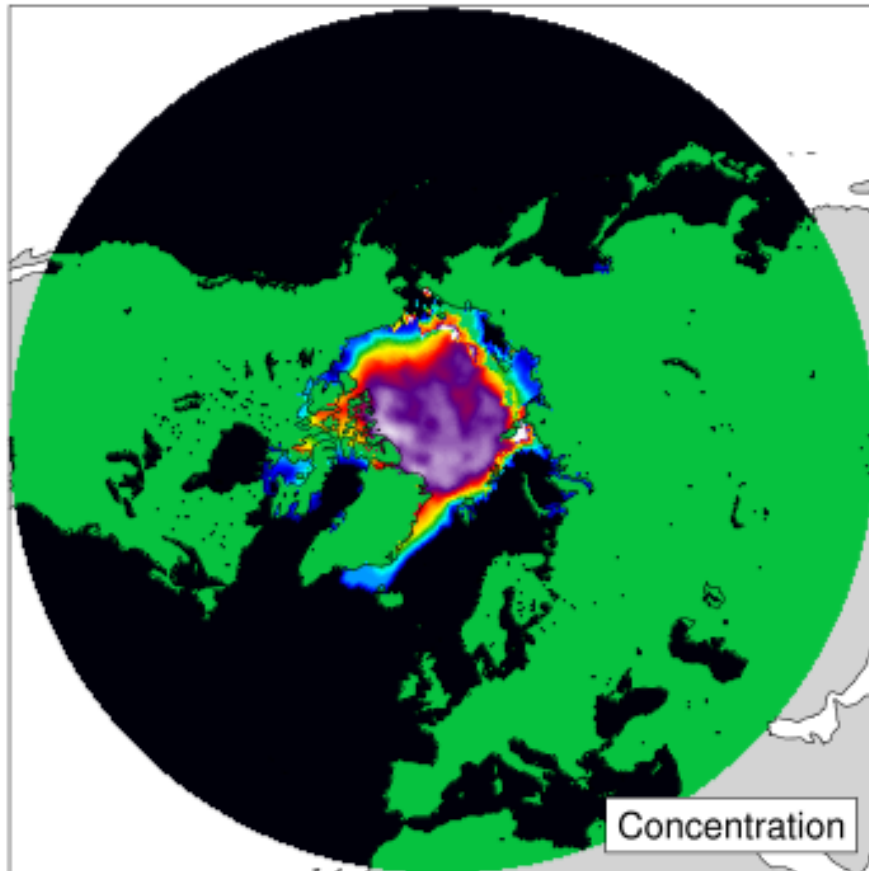
1901-1950

1951-2014

1854

1935

2012



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Conclusions

Methodology:

- **Different types of data can be synthesized, but the data fusion procedure (and its documentation) are nontrivial and iterative undertakings**
- **Analog approach for data estimation has advantages over alternative methods, but adds uncertainties including possible low biases due to prominence of recent decades in analog selection**

Analysis of output:

- **The recent retreat of sea ice is unique in the post-1850 period**
- **The recent loss of ice is much greater in summer than in winter -- consistent with climate model projections for future**

Next steps

- **Use of National Ice Center maps (gridded concentrations) as primary input for 1972-present**
- **Use of weights for different data sources covering same area/time**
- **Incorporation of additional data (e.g., Sea of Okhotsk, Shell)**
- **Development of user interface**
 - **time series plots of ice coverage at user-specified locations**
 - **time series of opening/closing dates, open-water season length**
 - **animations of concentration fields**